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ON THE SIGNIFICANCE OF VERTEBRAL COUNTS IN EXOCOETID TAXONOMY.

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Enumeration of the number of vertebrae in flying fishes for taxonomic purposes has been largely ignored by recent students of the group, including the present writers. In their case, at least, this disregard has been founded on two reasons. One of these, pragmatic, has been associated with the impossibility of obtaining such, in the absence of radiographic equipment, without the destruction of the specimens for other purposes. The other and important reason was a conviction that in this family the range was so slight and the variation relatively so great that without larger series than ordinarily available, little could be established that could not just as well be worked out on other more available characters. Nevertheless we are grateful to Dr. A. F. Bruun (1933) who has lately counted the vertebrae in a large number of species. Although the number of individuals counted in most species is small, he presents, notwithstanding, a valuable record of data. His examination of the current taxonomy of the Exocoetidae as referred to the vertebral count is interesting even if we can not subscribe to a number of his conclusions. The differences between our views and his, discussed herewith, seem to be inherent in differences in the diagnostic value placed on small variations in the number of vertebrae.

All of the current genera, *Fodiator*, *Evolantia*, *Halocypselus*, *Parexocoetus*, *Cypselurus*, *Hirundichthys*, *Exonautes* and *Prognichthys*, have been examined by Bruun and shown by him to have a range of from 35 to 52 vertebrae. The first four, which are exceptionally well differentiated genera on other characters, cover the entire range. The latter four genera, the "four-

winged" forms of very close affinities, have a range of from 41 to 52. Table I gives the data of Bruun arranged by genera. While there never has been any difficulty in separating these fishes generically, it is evident from the table that the vertebral counts could be of scant assistance if there were confusion on any other score. Comparing this table with the phylogenetic tree of Nichols and Breder (1928) however, there are certain items of interest to be mentioned in passing. Obviously, somewhere between the belonid ancestors and the advanced exocoetids, the Synentognathi have undergone a considerable reduction in the number of vertebrae. Evidences of this are now also apparent as generic characters within the family Exocoetidae itself, thanks to the work of Bruun. Thus, the line of two-winged forms shows a reduction of from 51–52 (*Evolantia*) to 41–45 (*Halocypselus*), and the line of high dorsaled forms from 38–41 (*Fodiator*) to 35–40 (*Parexocoetus*). The four-winged line, which Nichols and Breder (1928) indicated as differentiating at a point where the above two lines separated, thus appears to have never suffered such a large reduction, this assemblage showing a spread of 41–52. Within this group, if a divided second pectoral ray can be considered primitive then there has been a reduction in vertebrae in both pairs of genera as follows. *Cypselurus* 41–52 to *Prognichthys* 42–43, and *Hirundichthys* 45–47 to *Exonautes* 45. In all other Synentognathi known to the writers, the second ray is split, as would be expected. It is also to be noted that the primitive genus, *Evolantia*, has as high a count as any *Cypselurus*, presumably splitting off before vertebral reduction took place. After this, in the two-winged line, there was great reduction to *Halocypselus*. On the other hand great reduction took place on the line to the other primitive genus *Fodiator*, but before that genus appeared and continued, at a reduced pace, on to *Parexocoetus*. Thus it might seem that the line leading to *Fodiator* in the tree of Nichols and Breder (1928) should spring from some point well on to *Parexocoetus* rather than at its base, and this entire branch arise further along the *Cypselurus* stem than that of the two-winged forms. On the other hand, it would be a reasonable hypothesis that the four-winged forms again (secondarily) acquired an increased number of vertebrae, correlated with a more elongate body correlated with use of the ventrals in flight. It may be pointed out in this connection, however, that *Parexocoetus* with smaller ventrals farther forward, uses them in a seemingly analogous manner. The differences in their use, while not entirely evident superficially, become clear when referred to the principles of aerodynamics. The areas of the *Parexocoetus* ventrals are not sufficient to have an important lifting value but are sufficiently far back to give better control in flight, as compared with *Halocypselus*. The ventrals of the four-winged genera are definitely large enough to be of value for lift as well as maneuverability. Since, in aerodynamics, the farther rearward such a surface be placed the smaller it may be for maneuvering purposes, due to reasons of leverage, it becomes evident that the spreading of large ventrals in *Cypselurus* is important for lifting the after section of the body, since very small ones in such a position would suffice for tilting purposes. See Breder (1930) (1932) and Hubbs (1933) for other details.

For these broader aspects of phylogeny, as above discussed, the vertebral count is certainly of very real significance when considered in connection with other characters. Its application to the finer details of taxonomy, with the range of the group so small, we maintain, can only be of real value for the establishment of statistical forms involving the use of large series, certainly much larger than those mentioned by Dr. Bruun. For example, the large genus *Cypselurus* has a range of from 41 to 52 vertebrae and an individual variation of up to 3. Bruun himself wrote ". . . the range of variation determined with certainty within the single species is at most 3, but a larger material will probably be able to extend this by 1 or more . . . " This condition leaves room for only four distinct counts within the range of *Cypselurus*. It is also noted that the effect of temperature on the fragmentation of the column is thoroughly established for fishes, and that placing as much emphasis on this character as Bruun does might very well lead to fortuitous "species" dependent on climatic variations. That student recognizes the effect of temperature on vertebral number but considers it only in connection with phylogenetic importance, not mentioning its ontogenetic significance.

With these preliminary remarks the findings of Bruun may be discussed in detail, including both points of agreement and disagreement. Bruun states the high vertebral count "removes *Evolantia* considerably away from the other more primitive genera, *Fodiator* Jordan and Meek and *Parexocoetus* Bleeker." With this we entirely agree as has already been indicated.

A new subspecies, *Fodiator acutus pacificus* Bruun, has been erected for the American fishes on the following data. "The *Fodiator* material consists of 3 specimens from West Africa (Hamburg Zool. Museum) and 1 from the Bay of Panama. The 3 Atlantic specimens have 38–39 vertebrae, the Pacific 41. The difference thus shown between the Pacific and the Atlantic individuals seems, along with a number of other smaller, yet distinct differences in proportion and fin-ray characters, to justify the separation of the Pacific *Fodiator* as a special subspecies, *pacificus* n. subsp. of the Atlantic *F. acutus* C. et V." While we have no philosophical objection to statistical subspecies, we certainly question the validity of erecting one, with the only recognizable difference mentioned in the description being 2 vertebrae, based on a single specimen. The above quotation is the full description.

Of the separation of *Parexocoetus mesogaster* and *mento* a somewhat better case is made out, being based on 14 fishes, with again a separation of 2 vertebrae. The erection of a new subspecies *Parexocoetus mento atlanticus* Brunn, certainly stands as a nomen nudum with its description quoted below.

"Of this species, which is so well characterized by the number of vertebrae, I have found 2 specimens in the British Museum's collections from the eastern, tropical Atlantic, which I think provisionally belong to a special subspecies owing to minor differences from the Indo-Pacific specimens: *P. mento atlanticus* nov. subsp." This, following a criticism of others for inadequate descriptions, is difficult to understand as is also the immediately succeeding statement, following the above quotation. "Examination of Breder's material will probably determine at once whether it should

be referred to this subspecies, which owing to its apparently close relationship with the Indo-Malayan *P. mento* may certainly be expected to have no barbel in the early stages." This statement refers to a question raised by Breder (1932) concerning the possible specific differences of juvenile Atlantic *Parexocoetus* with and without barbels. If the unbarbled young studied by Breder, and the barbled young studied by Hildebrand and Cable (1930), eventually are shown to have a different vertebral count, it would certainly go far to clear the matter up.

Cypselurus comatus (Mitchill) is revived as a species from the synonymy of *C. heterurus* where it has long reposed as a young form. This is done on a basis of its 41–42 vertebrae, as compared with the 45 of *heterurus* which seems to us a questionable specific difference. With the reference of *C. antarei* Beebe and Hollister (1933) to *comatus*, we are provisionally in agreement, and are satisfied with Dr. Bruun's placement of *C. naresi* (Gunther) near it, as supposedly he has seen this material which we have not. On the other hand it may be that *C. antarei* represents the young of *C. lutkeni* or *C. vitropinna*, both of which are close to *C. heterurus*.

According to Bruun, *Cypselurus smithi* Breder and Nichols, is identical with *C. nigricans* (Bennett). This fish (*C. nigricans*), Nichols (1924) referred to the Pacific, considering those specimens recorded from the Atlantic as the nearly identical *C. furcatus*. Since *C. smithi* and *C. nigricans* have identical vertebral counts according to Bruun, they may still be separated by the original points of differences indicated by Breder and Nichols (1930) and Nichols and Breder (1930). Actually, *C. smithi* much more closely resembles *C. bahiensis* than it does *C. nigricans* or *C. furcatus*, as is fully indicated in those two papers.

Apparently Bruun would refer *C. vitropinna* to *C. heterurus* or *C. comatus*, depending on what vertebral count it has. Since, on examination, we found *C. vitropinna* to have 46 vertebrae its identity with *C. comatus*, according to Bruun's criteria, is out of the question. While it is evident that *C. vitropinna* is close to *C. heterurus* as already mentioned by Breder (1927), Parr (1930) and Nichols and Breder (1930), the species in question is certainly not as close to *heterurus* as it is to *C. lutkeni* (Jordan & Evermann) which is clearly differentiable from it, independently of what the vertebral count may be, and over which so far no question has been raised. Although Bruun has just revived *C. comatus* from the synonymy of *C. heterurus*, it is certainly possible that the young of all three of the species, *heterurus*, *lutkeni* and *vitropinna*, are of the *comatus* type. Any taxonomic changes based on other than a developmental series would, in our judgment, be open to question.

The supposed similarity or identity of *C. monroei* Nichols and Breder, to *C. bahiensis*, we can not understand at all. In fact Breder and Nichols (1930) considered the adult so different from other species of *Cypselurus* that they wrote, "A new genus could doubtless be erected for this species..."

Reference to the various papers mentioned must be made to understand completely the reasons for our inability to accept Dr. Bruun's attitude on these three species. However, we have gathered certain figures together and assembled them in a cut, in the conviction that their comparison alone

should be sufficient to satisfy most ichthyologists that the differences displayed are of specific rank, in spite of the similarity of any single character such as the vertebral count.

We have also had radiographs made of fourteen specimens for the purpose of further considering the significance of the vertebral counts in these species.[1] The data so obtained is displayed in Table II. Since these figures add nothing, the range of generic variation obtained by Bruun, Table I, is modified in no way by this additional material.

Our inability to accept the race *Fodiator acutus pacificus* on the basis of one specimen with 41 vertebrae instead of 38 or 39 is strengthened by our radiographs of two Pacific *Fodiator* from a nearby locality, each with 39. The publication of a description of "a number of other smaller, yet distinct differences in proportions and fin-ray characters" which are so far undefined, would be necessary to render this proposed race valid, if they are sufficiently important.

The vertebral counts of the present material of *Parexocoetus* (from the Atlantic) exactly coincide with those of Bruun for *P. mesogaster* as defined by him. This, unfortunately, gives no aid in defining the nomen nudum *P. m. atlanticus.*

The various species of *Cypselurus* examined show only a range of from 44 to 46 vertebrae and are consequently of no taxonomic value in separating these forms. Table II gives the comparative data. It does, however, clearly show that none of our fish can be *C. comatus,* if, as Bruun contends, the low count (41–42) is diagnostic of that form.

TABLE NO. I.

Comparison of Exocoetid Vertebral Counts, based on the data of A. F. Bruun.

GENERA	NUMBER OF VERTEBRAE. (UROSTYLE COUNTED AS LAST VERTEBRA.)																	
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Evolantia																	x	x
Fodiator				x	x		x											
Halocypselus							x	x	x	x	x							
Parexocoetus	x	x		x	x	x												
Cypselurus							x	x	x	x	x	x	x	x	x	x	x	x
Hirundichthys											x	x	x					
Exonautes											x							
Prognichthys								x	x									

[1]We are grateful to Dr. W. Antopol of the Mt. Sinai Hospital, New York City, for having the radiographs made which are here discussed.

Evolantia.....*E. microptera*, 4 specimens.
Fodiator.....38–39 *F. acutus acutus*, 3 specimens.
41 *F. a. pacificus*, 1 specimen.
Halocypselus.....? –44 *H. evolans*; ? –45 *H. obtusirostris*.
"large number"
Parexocoetus.....35–36 *P. mento* and *P. m. atlanticus*, 4 specimens;
38–40 *P. mesogaster*, 10 specimens.
Cypselurus.....41–42 *C. comatus*; 45 *C. furcatus* and *heterurus*;
49 *C. californicus*; 51–52 *C. lineatus* (other species, *C. bahiensis* and *nigricans* and *smithi* mentioned as in this range between *comatus* and *furcatus*).
Hirundichthys.....45 *H. speculiger* (others not named).
Exonautes.....*E. rondeletii*, 1 specimen.
Prognichthys.....*P. gibbifrons*.

TABLE NO. II.

Vertebral Counts of mostly American Museum of Natural History Material Compared with Some of Dr. Bruun's counts.

SPECIES	NUMBER OF VERTEBRAE. (UROSTYLE COUNTED AS LAST VERTEBRA.)	
	A.M.N.H. MATERIAL	BRUUN'S COUNTS.
Fodiator acutus	39 (2)[1]	38, 39, 41 (4)[2]
Parexocoetus mesogaster	38, 39, 40 (5)[3]	38, 39, 40 (10)
Cypselurus bahiensis	46 (1)	....
Cypselurus lutkeni[4]	44 (1)	....
Cypselurus vitropinna[5]	44 (1)	....
Cypselurus heterurus	46 (1)	45
Cypselurus furcatus[6]	45 (1)	45
Cypselurus monroei[7]	45 (1)	....
Cypselurus smithi[8]	44 (1)	....
Cypselurus comatus	.....	41–42

[1]Numbers in parenthesis represent number of specimens.
[2]The one fish with 41 vertebrae from the Bay of Panama, Bruun considers a new race *F. a. pacificus*. Compare with the present material from Bahia Hundu, Panama. See Table I and text. Bingham Oceanographic Collection.
[3]Three specimens from the Dry Tortugas from the material of Breder (1929) (1932) which Bruun refers to, had 38, 39, 40 vertebrae, the others from Diamond Shoal lightship 39 and 40, obtained through the kindness of Mr. Van Campen Heilner.
[4]Figured by Breder and Nichols (1930).
[5]Paratype. Bingham Oceanographic Collection.
[6]Figured in accompanying plate.
[7]Figured by Breder and Nichols (1930).
[8]Paratype.

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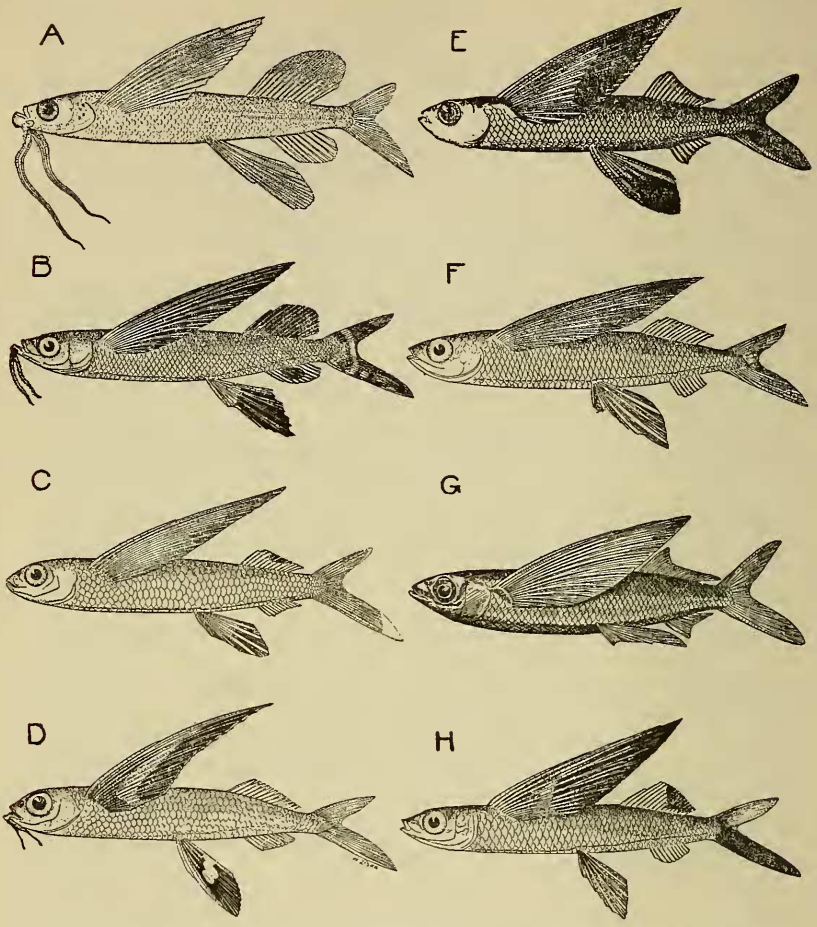

Fig. 1. Comparative plate of the species of *Cypselurus* under discussion.

A. *C. monroei* (young) Type 48 mm. s. l. Nichols and Breder 1928; 432.
B. *C. monroei* (adult) 151 mm. s. l. Breder and Nichols 1930; 2.
C. *C. bahiensis* 230 mm. s. l. Nichols and Breder, 1930; 2.
D. *C. furcatus* 150 mm. s. l. (Mentioned by Breder and Nichols 1930, 3) original.
E. *C. heterurus* 178 mm. s. l. Smith 1907; 167 (In Smith's Fishes of North Carolina as *C. lutkeni;* not of Jordan and Evermann 1896 or Breder and Nichols 1930. (See synonymy of Nichols and Breder 1930.)
F. *C. lutkeni* 241 mm. s. l. Breder and Nichols 1930; 6.
G. *C. vitropinna* Type 183 mm. s. l. Breder 1927; 20.
H. *C. smithi* Type 200 mm. s. l. Breder and Nichols 1930; 5.